Section 4. This is because the estimates in Section 4 made the conservative assumption to treat the entire GLONASS constellation as either available or not available. This is equivalent to degrading unexpectedly to an all-GPS environment in a comparison-type algorithm.

For precision approach operations, some differential overlay is absolutely required. As with NPA, a continuity impact may exist under very conservative assumptions. If so, the effect would be equivalent to that discussed in Section 4.

For surface operations, RNP is currently undefined. Nevertheless, given the 2-dimensional nature of the problem, the necessity for a differential overlay, and the lack of safety concerns, no operational impact is foreseen.

Appendix B

Impact of a Bad Upload

Both GPS and GLONASS have experienced during their developmental phases so-called "bad uploads", in which the navigation data uploaded to the spacecraft for subsequent downlink to the users are incorrect. In the absence of a differential overlay, such a situation may render the affected spacecraft unusable. Even **with** the planned differential overlay, nearly all of these upload error problems can be quickly detected and corrections provided to the users. However, if multiple spacecraft are affected, the constellation could become effectively unusable until the data are corrected. This is a serious concern, and both GPS and GLONASS take special precautions to prevent it from occurring. The incidence of such events can be expected to decline in the future for the operational constellations to an extremely small value, although some low probability of occurrence will always remain. This is one of the driving factors behind the need for a widely-available differential overlay that provides integrity, such as the WAAS.

If uploads (and subsequent navigation message switchovers) are managed such that mutually visible spacecraft do not switch their navigation messages simultaneously, a bad upload could be considered as only one additional cause of a short-term satellite outage. Given the very low probability of a bad upload, relative to other planned and unplanned short-term satellite outages, this formulation would imply a marginal impact on overall satellite availability statistics and resulting navigation performance. The conclusions presented earlier, for MES impact on GNSS operations, therefore would be unchanged.

If uploads are managed such that multiple mutually visible spacecraft are simultaneously affected, a potentially significant issue of navigation continuity and even integrity (under RAIM) may exist. This would be a serious matter for any GNSS user. This appears to be more of a GNSS operational control concern than a Globalstar MES concern.

Uploads should be managed in a non-simultaneous manner to the maximum extent possible, and continuing efforts are warranted to build in precautions against bad uploads, and to create rapid recovery procedures.

Appendix C

RFI Mitigation Techniques for GNSS Receivers

There are multiple sources of RFI potentially relevent to GNSS, and the aviation community is currently examining the overall RFI issue with the intent to review current standards for RFI mitigation. Technological solutions exist that would allow GNSS receivers to tolerate higher levels of RFI than implied by ARINC Characteristic 743A-1. Some of these may be incorporated in future standards for GNSS receivers intended to support sole-means navigation and approach/landing. Selected techniques are noted below. Their effectiveness for the particular forms of RFI generated by Globalstar MES operations will depend on the precise design of the MES, its operating regime, the relative geometry between the MES and the GNSS receiver, and the gain pattern of the GNSS antenna in the direction of the MES.

1. Adaptive filtering in the frequency domain. This technique would mitigate narrowband signals, narrowband intermodulation products and spurs in the GPS or GLONASS portions of the spectrum.

2. Increased emphasis on front-end linearity and dynamic range. In the presence of very strong RFI, virtually all communications and navigation receivers will eventually reach a condition where the front end operates nonlinearly. In this condition, signals are distorted and intermodulation products can develop inside the receiver. By focusing on improved linearity and dynamic range, future receivers could preserve the information contained in the received navigation signals at higher levels of RFI (relative to current equipment).

3. Blankers and limiters. These circuit elements are intended to mitigate very strong pulsed interference. Under normal operation, they are effectively transparent. However, with the onset of a very strong pulse of RFI, they will either limit the amount of energy passed to the subsequent circuit to a preset maximum level, or literally "blank" the signal for the duration of the pulse. In this way, the impact of strong pulsed RFI on circuit elements which integrate received energy is mitigated.

4. Vector tracking loop implementation. In all currently-available commercial GNSS receivers, each satellite signal is individually tracked in terms of its code state (group delay). Most receivers also track the carrier, to provide a more accurate and stable estimate of code state as well as relative velocity information (range-rate). Each tracking loop separately correlates to a single satellite signal (PRN code), treating all other signals as broadband noise. The tracking loops individually send information to the navigation filter, which merges the information into a single navigation solution. ARINC Characteristic 743A-1 specifies the J/S ratio for such a configuration, where the signal energy is that for a single satellite signal. An alternative configuration takes the tracking feedback from the navigation filter instead of the correlation process on a single signal -- error signals are still sent to the navigation filter as before, but the error signals are not "turned-around" on a per-channel basis for tracking. The effect of this change is to make the overall tracking process more robust by a multiplicative factor equal to the number of signals being tracked. For example, if five signals are being tracked (the minimum for navigation with fault detection), the tracking process would be 7 dB more robust than an equivalent circuit with individual tracking loops. If 10 signals are being tracked, the vector tracking loop would be 10 dB more robust than an equivalent implementation of single, or scalar, tracking loops. Surprisingly, the computational complexity of the vector tracking loop is no higher than the computational complexity of the standard implementation. However, the vector tracking loop may require a shorter cycle time through the navigation filter.

5. Adaptive antenna nulling. This technique relies on a more complex antenna with special processing to place a spatial null on received signals that do not appear to satisfy prespecified criteria. For example, an adaptive antenna could sense the signal power of all signals arriving from discrete directions, and null out the N largest signals that are not arriving from directions associated with known GNSS navigation sources. This technique is the most general and powerful for broad classes of RFI, but requires a more sophisticated antenna with a substantial (TBD) cost impact to the user.

Other innovations may be applicable, and may be developed in the future.

MES/GLONASS LINK MARGIN ASSESSMENT

Assumptions:

1. MES channels are on 1.23 MHz centers starting at 1610.865 MHz
2. MES out-of-band emissions are characterized by IM skirt and broadband noise
3. GLONASS channels are on 562.5 kHz centers; Chnl 0 is 1602 MHz
4. A GLONASS receive channel will effectively filter the MES spectrum with a squared sin(x)/x filter characteristic whose null-to-null passband = 1.022 MHz

$i := 1, 2 .. 13$ Index for Globalstar channels

$j := -6, -5 .. 24$ Index for GLONASS channels

$MES\_freq_i := 1610.865 + 1.23 \cdot (i - 1)$ Subscript is from 1 to 13

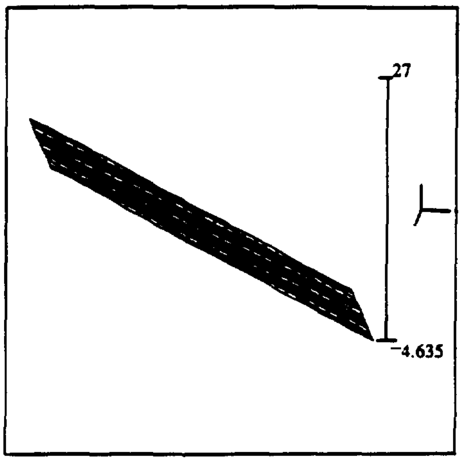
$GLON\_freq_{j+7} := 1602 + 0.5625 \cdot j$ Subscript is from 1 to 31; chnls from -6 to 24

$Freq\_offset_{i,(j+7)} := MES\_freq_i - GLON\_freq_{j+7}$

$Freq\_offset_{1,1} = 12.24$

Define MES emission spectrum (dBW/MHz)

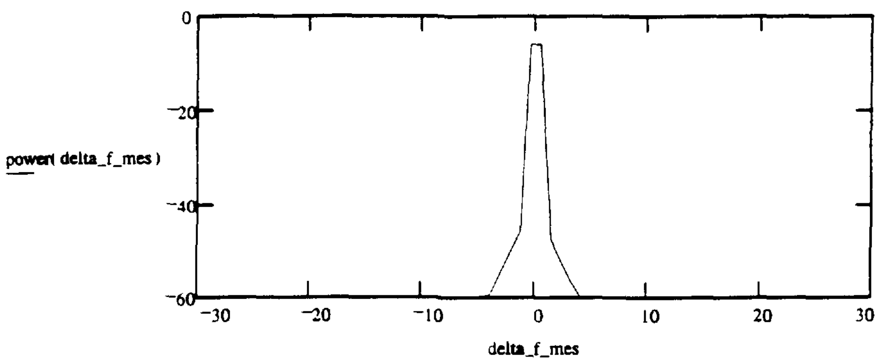
$$freqs := \begin{bmatrix} -35 \\ -4 \\ -0.615 \\ -0.614 \\ 0.614 \\ 0.615 \\ 4 \\ 35 \end{bmatrix} \qquad powers := \begin{bmatrix} -60 \\ -60 \\ -43 \\ -6 \\ -6 \\ -43 \\ -60 \\ -60 \end{bmatrix}$$



Freq_offset

$delta\_f\_mes := -30, -29.1 .. 30$

$power(delta\_f\_mes) := linterp(freqs, powers, delta\_f\_mes)$



Calculate equivalent RFI signal power in a GLONASS channel

$$f\_lo_{i,(j+7)} := Freq\_offset_{i,(j+7)} - 0.511$$

$$f\_hi_{i,(j+7)} := Freq\_offset_{i,(j+7)} + 0.511$$

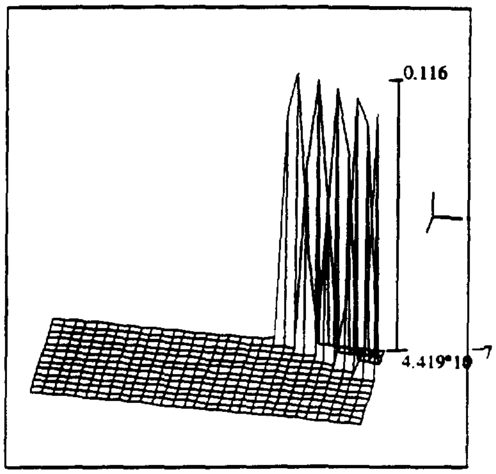
$$Power\_rfi_{i,(j+7)} := \int_{f\_lo_{i,(j+7)}}^{f\_hi_{i,(j+7)}} \left[\frac{\sin\left(\pi \cdot \frac{f - Freq\_offset_{i,(j+7)}}{0.511} \right)}{\pi \cdot \frac{f - Freq\_offset_{i,(j+7)}}{0.511}} \right]^2 \cdot 10^{\frac{\mathrm{linterp}(freqs,\, powers,\, f)}{10}} \, df$$

$$Power\_rfi\_db := \overrightarrow{(10 \cdot \log(Power\_rfi))}$$

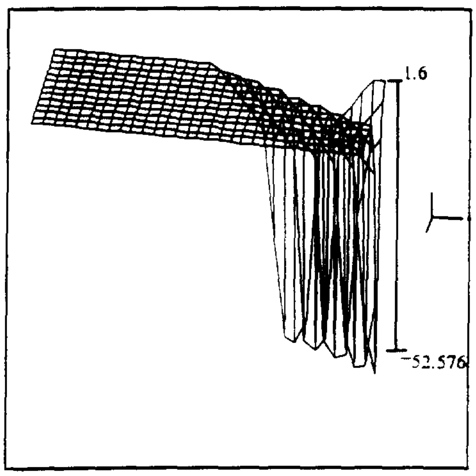
$$Margin\_db := \overrightarrow{(-61.947 - Power\_rfi\_db)}$$

$$Sigma\_db := \frac{\overrightarrow{Margin\_db + 4.5}}{3.6}$$

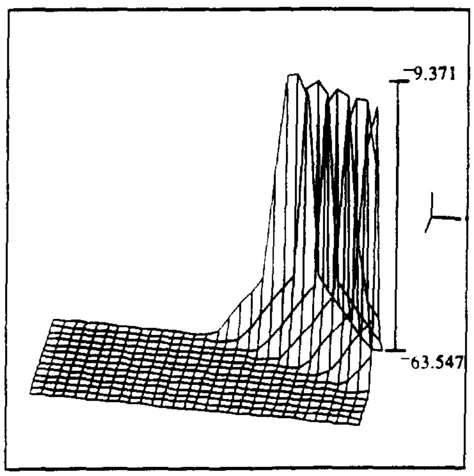
$$Prob\_exceed := \overrightarrow{(1 - \mathrm{cnorm}(Sigma\_db))}$$



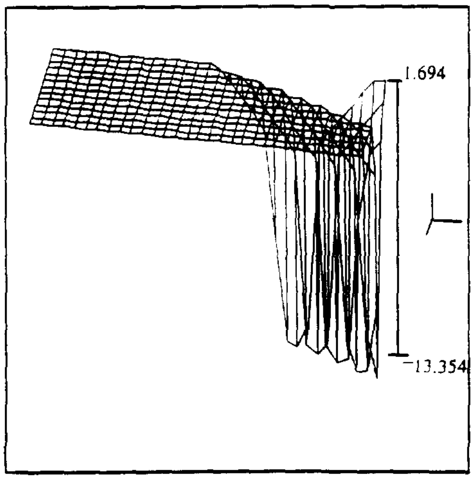
Power_rfi



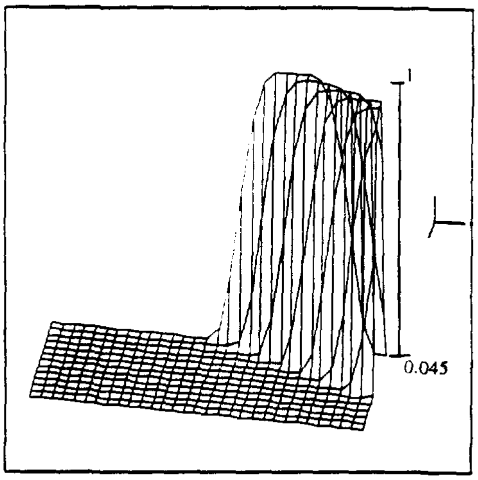
Margin_db



Power_rfi_db



Sigma_db



Prob_exceed

NOTES:

1. The plot of Power_rfi is in Watts radiated by an MES in a Glonass channel; the x-axis is Glonass channel ID and the y-axis is Globalstar MES channel assignment. The x and y axes have the same interpretation on all subsequent plots.

2. The plot of Power_rfi_db simply converts Power_rfi to dBW.

3. The plot of Margin_db translates the analysis to the GNSS receiver antenna port, and incorporates all link losses contained in the nominal link budget for Glonass. Note that the "best case" is a positive margin of 1.6 dB.

4. The plot of Sigma_db accounts for the probabilistic link budget parameters by shifting the expected link margin 4.5 dB, and dividing by the standard deviation of the variable parameters of 3.6 dB. The calculated result is the number of "standard deviations above the mean" at which the link would be operating for a particular case, in order to exceed the specified J/S threshold of 22 dB.

5. The plot of Prob_exceed illustrates the probability that a normally-distributed random variable would exceed the value of Sigma_db determined for each particular channel pairing. Note that the assumption of a normal distribution (for the sum of variable link budget parameters) is only a rough first approximation.

ATTACHMENT 2

INTERNATIONAL TELECOMMUNICATION UNION

RADIOCOMMUNICATION STUDY GROUPS

Delayed Contribution
Document 2-2/27-E
25 January 1994
Original: English only

Received: 25 January 1994

United States of America

WORKING DOCUMENT TOWARDS A DRAFT NEW RECOMMENDATION

SIMULATION OF INTERFERENCE INTO ANALOG RADIO-RELAY ROUTES FROM LOW-EARTH ORBITING SATELLITES OF THE LEO D MOBILE-SATELLITE SERVICE SYSTEM

1.0 Introduction

This document describes the results of computer program simulation for interference into an analogue angle-modulated radio-relay network from a low-Earth orbiting (LEO) satellite constellation operating in the mobile-satellite service (MSS) when both systems share the same spectrum. The computer simulation program is described in Document 9D/TEMP/31(Rev.1)-E and its annexes. The MSS system used in this simulation closely resembles the system described as LEO D in Document 8D/TEMP/43(Rev.3)-E. A number of example sharing scenario situations and their results are described.

2. Description of the Input Parameters

Table 1 represents the input data required for the computer simulation to describe the MSS LEO D system. A description of the computer simulation and the data describing the analog radio-relay system is the same as that described in Document 9D/TEMP/31(Rev.1)-E. The simulation is performed for various pfd mask levels that result from transmissions from each satellite in the constellation. The LEO D MSS system incorporates a 100 percent frequency reuse factor in each of the sixteen beams used in the space-to-Earth service link which results in a pfd mask from each satellite at the surface of the Earth. This pfd mask is defined as a function of elevation angle (Ø) at a point on the Earth's surface to the MSS satellite as follows:

Y $dBW/m^2/4$ kHz	for 0 _ Ø _ 5 degrees,
Y + 0.05 (X - Y) (Ø-5) $dBW/m^2/4$ kHz	for 5 < Ø _ 25 degrees, and
X $dBW/m^2/4$ kHz	for 25 < Ø _ 90 degrees.

System Parameter	Value
Satellite Orbit Altitude	1414 km
Number of Satellites	48
Number of Satellite Orbital Planes	8
Orbit Inclination	52 degrees
Number of Satellites per Plane	6
Satellite Separation	60 degrees
Longitude of the Ascending Node for Each Plane	0, 45, 90, 135, 180, 225, 270, and 315 degrees
Satellite Phasing between Planes	7.5 degrees*
Space-to-Earth Service Link Frequency	2500 MHz
Frequency Reuse Factor	1.0
Length of Simulation (Set equal to satellite track repeat period)	Every 25 orbits or 47.5 hours
High Angle Satellite pfd Level	X dBW/m^2/4 kHz
Low Angle Satellite pfd Level	Y dBW/m^2/4 kHz

* 0 degrees was used in the simulation

Table 1 Interference Simulation Input Parameters for the LEO D MSS System

3. Simulation Results

Recommendation 357 defines both a short- and long-term limit of interference that is allowed into an analogue angle-modulated radio-relay system in bands shared with the Fixed-Satellite Service (FSS). A linear interpolation of the interference limits defined in Rec. 357 are plotted on the right hand portion in the graphs of results appearing in Figures 1 through 3. The curves to the left in each figure represent the interference into the most affected radio-relay route for the MSS LEO/FS sharing scenario being considered.

Figure 1 presents the simulation results of interference into a FS network at three different latitudes where the high and low angle pfd levels are X = -132 dBW/m^2/4 kHz and Y = -152 dBW/m^2/4 kHz, respectively, for each satellite in the 48 satellite constellation for the LEO D MSS system. Note, that for a FS station at any of the three latitudes shown, the resulting interference levels into the FS network are at or below the limits stated in Rec. 357.

Since the FS site at a latitude of 40 degrees provided the highest interference scenario in Figure 1, the interference simulation was repeated for three different sets of pfd limits at a space-to Earth service link frequency of 1600 MHz at this 40 degree latitude with the results being shown in Figure 2. Note, that all three simulation results exceeded the desired interference levels by about a factor of 3 dB or less. Since the LEO D system does not operate at this service link frequency it would not apply to LEO D; however, the results are provided as additional information.

Figure 3 presents the interference results at two different frequency bands for an FS site at 40 degrees latitude with X/Y pfd levels of –139/–149. Note, that operation at 2500 MHz (where the LEO D system is proposed to operate) is within the interference limits by about a factor of 3 dB and that operation at 1600 MHz exceeds the limits by about a factor of 3 dB.

4. Potential Improvement over Simulation Results

It is anticipated that actual performance would be better than the simulation for a variety of reasons. One reason is that every satellite in the MSS system would be not be continuously operating at its specified mask level due to variations in traffic loading, operational considerations, spacecraft antenna design constraints, antenna polarization, etc. The common spectrum between the frequency plan of the FS network and the MSS system may result in less than 50 hops being affected by the MSS satellite transmissions. Two other reasons for expecting improved performance are satellite phasing and a new proposed FS reference radiation pattern.

The above simulations did not include the LEO D satellite phasing which provides a 7.5 degree increasing phase difference between orbital planes, such that, after proceeding in either direction around the equatorial plane by eight planes there would be an accumulated shift of 60 degrees which is the separation between satellites in a plane. The 7.5 degree phase shift between planes then does not allow for more than one satellite to be crossing the equatorial plane at any one time in a South-to-North manner. This should prevent the mainbeam of any one FS receive antenna from having more than one MSS satellite in view from the LEO D constellation. With 0 degrees phasing the condition does exist where more than one MSS satellite would be within the mainbeam of the FS antenna.

Another consideration is the draft Revision of Recommendation 699-1 as described in 9B/TEMP/31(Rev.1)-E. This would decrease the sidelobe pattern by 3 dB and is to account for the aggregate interference in the sidelobes. For the reference 33 dB gain FS antenna, this would reduce MSS interfering signals from about 5 degrees out to 48 degrees off the FS main beam.

These last two factors can be accounted for in future simulations. Taken together all the above reasons may provide lower interference levels into an FS network over that which has been presented.

5. Conclusion

The computer based interference analysis tool described in Document 9D/TEMP/31(Rev.1)-E provides a starting point for analyzing interference from LEO MSS systems into FS networks. With modifications to this program to accommodate the characteristics of individual MSS systems and multiple MSS systems operating co-frequency and co-coverage, this analysis tool could become extremely valuable in developing pfd emission levels for LEO satellites. Further study is required in this area.

Based upon the these computer interference simulations and the likelihood of more than one MSS system operating co-frequency and co-coverage with another MSS system, it may be possible to impose pfd limits on MSS satellites which are higher than those specified in Radio Regulation No. 2566. These limits per Footnote No. 753F (WARC-92) apply to MSS systems operating in the 2483.5-2500 MHz band. Based upon the preceding simulation results for the LEO D MSS system and potential improvements described in section 4. plus the fact that different MSS systems will generate different interference statistics, a proposed pfd mask for each satellite when operating in a multi-system MSS environment in the 2483.5-2500 MHz band is:

-149 dBW/m^2/4 kHz	for $0 \leq Ø \leq 5$ degrees,
$-149 + 0.65\,(Ø-5)$ dBW/m^2/4 kHz	for $5 < Ø \leq 25$ degrees, and
-136 dBW/m^2/4 kHz	for $25 < Ø \leq 90$ degrees.

Figure 1

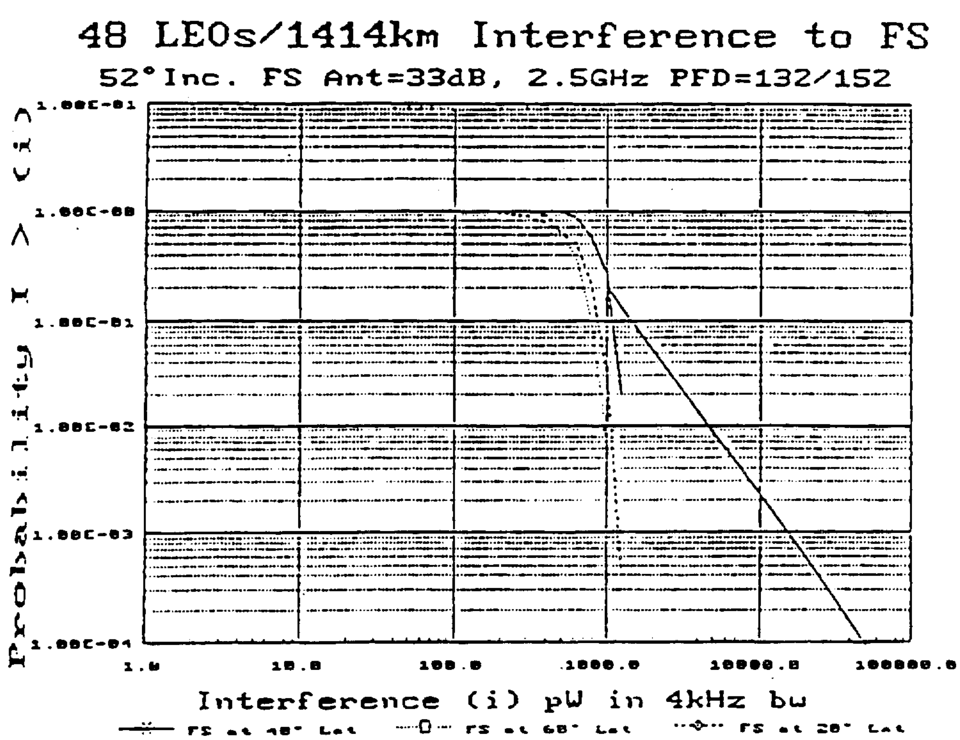


Figure 2

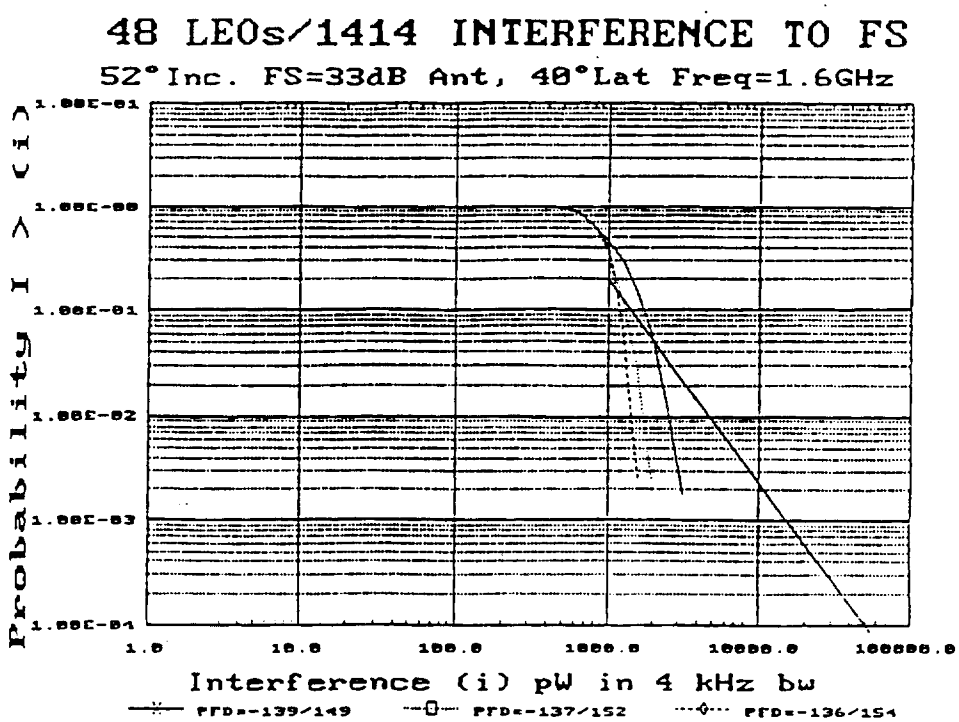
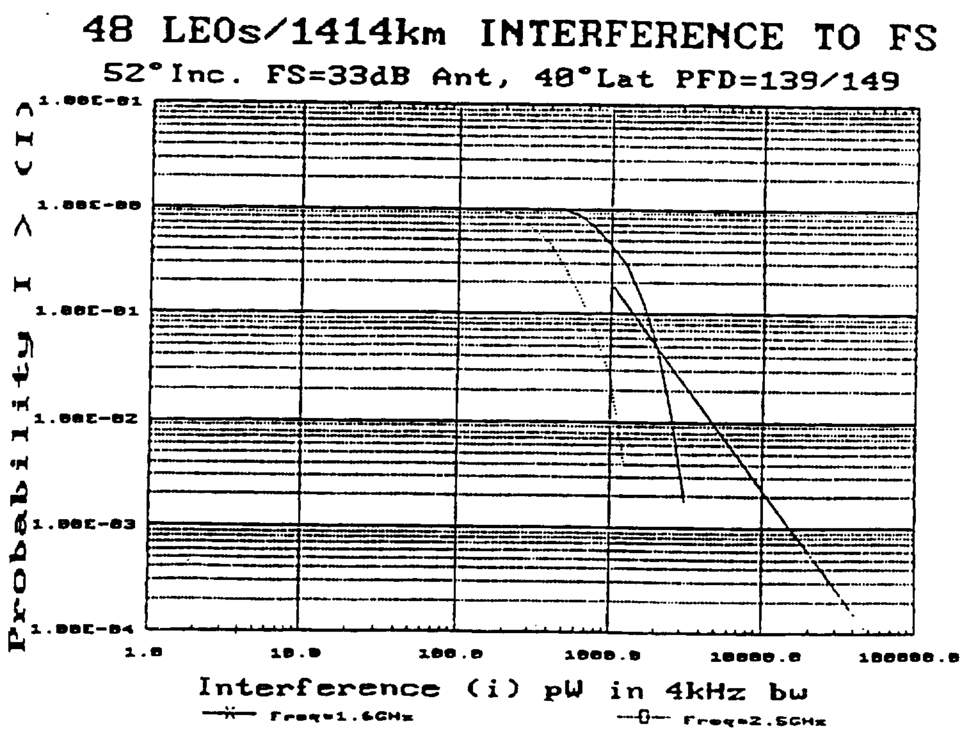


Figure 3



ATTACHMENT 3

Field Measurement of ITFS Interference in San Francisco Bay Area

Field measurements of ITFS interference were made throughout the San Francisco Bay Area to determine the effect on wideband CDMA MSS MES receiver performance.

A search was performed to identify the ITFS transmitters in the San Francisco Bay Area. The ITFS transmitters which would be anticipated to produce the greatest interference into the MSS band of frequencies, 2483.5 to 2500 MHz, would be those operating at the lowest ITFS channel allocation, 2500 to 2506 MHz, designated ITFS Channel A1. An ITFS transmitter operating on Channel A1 was identified on Grizzly Peak overlooking Berkeley, California. In parallel with the field measurements, information was gathered concerning ITFS transmissions in general and the Grizzly Peak transmitting site in specific.

A single day's measurement campaign was carried out in a counter-clockwise circumnavigation of the San Francisco Bay on Tuesday, March 15, 1994, to travel to and then within the area served by the ITFS transmitter on Grizzly Peak.

A van was equipped with (1) a roof-mounted, omni-directional in azimuth antenna, (2) a low-noise preamplifier adjacent to the antenna, (3) a spectrum analyzer as a receiver, and (4) a portable personal computer as a controller and data recorder. Results of the field tests were fed into a laboratory simulation so that evaluations of the situation could be performed in controlled, repeatable tests.

Spectrum of ITFS Transmitter

The two spectra shown in Figure ITFS-1 "Spectrum of ITFS Channel A1 Located at Grizzly Peak, Berkeley, CA" are of the same ITFS transmitter. The upper trace is taken using a 1 MHz resolution bandwidth setting of the spectrum analyzer, while the lower trace is taken using a 10 kHz resolution bandwidth. Each frequency data point indicates the maximum of 23 sweeps of the spectrum during a 2 minute period. (The 601 points of data recorded from each spectrum analyzer sweep have been post processed to reduce the number of points to 200 by selecting the maximum point of each set of 3 points, in order to fit within the 256 column limitation of an Excel spread sheet. The maximums of 23 sweeps were selected at each of the 200 post processed frequencies points for this chart.) The data taken just below the ITFS transmitting site.

The peak of the synch pulses in the time domain is the level of the unmodulated visual carrier, and therefore the peak carrier level can only be measured accurately in a relatively wide bandwidth. The synch pulses of the TV signal require a bandwidth of at least 300 kHz to reach full response.

At 1 MHz bandwidth (approximating the Globalstar 1.25 MHz bandwidth), the selectivity of the spectrum analyzer is such that sweeping through the ITFS carrier causes the response of the spectrum analyzer resolution-bandwidth filter to be traced out. Hence the upper trace indicates only the filter characteristic from about 2.498 to beyond 2.502 GHz, and masks the weaker lower vestigial sideband of the ITFS signal from 2.499 to 2.500 GHz.

At 10 kHz bandwidth, the sidebands of the ITFS signal can be observed. However, there is not a full response to the peak carrier signal in the narrower bandwidth. This gives rise to some doubt of the levels of peak (maximum) responses within the ITFS sidebands.

The specifications for the selectivity of the HP8561E spectrum analyzer states a bandwidth ratio of 1:15 for levels of -3 dB to -60 dB. To observe the FCC emission limit of -60 dB at 1 MHz carrier causes the response of the spectrum analyzer resolution-bandwidth filter to be traced out. Hence the upper trace indicates only the filter characteristic from about 2.498 to beyond 2.502 GHz, and masks the weaker lower vestigial sideband of the ITFS signal from 2.499 to 2.500 GHz.

At 10 kHz bandwidth, the sidebands of the ITFS signal can be observed. However, there is not a full response to the peak carrier signal in the narrower bandwidth. This gives rise to some doubt of the levels of peak (maximum) responses within the ITFS sidebands.

The specifications for the selectivity of the HP8561E spectrum analyzer states a bandwidth ratio of 1:15 for levels of -3 dB to -60 dB. To observe the FCC emission limit of -60 dB at 1 MHz below the lower band edge of ITFS channel A1– where the band edge itself is 1.25 MHz below the ITFS carrier – requires a spectrum analyzer (double-sideband) bandwidth of less than 4.50 MHz (twice 2.25 MHz) at the -60 dB selectivity level. The 1:15 bandwidth ratio then requires selecting a spectrum analyzer (-3 dB) bandwidth of less than 300 kHz.

Specifications for ITFS Emissions, Spectrum Analyzer Selectivity, and CDMA Receiver Selectivity

• The FCC Emission Limits for ITFS transmitters is from FCC Rules Part 74.936.

> "...the maximum out-of-band power of a transmitter operating in this service shall be attenuated 38 dB relative to the peaks visual carrier at the channel edges and constant slope attenuation from this level to 60 dB relative to the peak visual carrier at 1 MHz below the lower band edge... All out-of-band emissions extending beyond these frequencies shall be attenuated at least 60 dB below the peak visual carrier power."

• The HP 8561E specification is from the Hewlett Packard Test & Measurement Catalog 1994.

See Figure ITFS-2 "Measured Spectrum Analyzer Selectivity".

> "**Selectivity** (-60 dB/-3 dB)
> **RBW>300 Hz:** <15:1"
>
> The 60 dB bandwidth would then be 15 MHz, or in other words, the -60 dB selectivity points would be ±7.5 MHz.
>
> The measured selectivity (by sweeping through a CW signal from a test generator) is -22 dB at the ITFS carrier frequency when the spectrum analyzer center frequency is tuned to the center of the highest MSS channel. The measured -60 dB selectivity points are -3.63 and +4.15 MHz, and the -3 dB selectivity points are -0.530 MHz and +0.517 MHz for a 3 dB bandwidth of 1.047 MHz.

• The Globalstar CDMA receiver specification is from the "Globalstar CDMA/AMPS Dual-Mode Portable User Terminal Specification", 80-25013-1, February 7, 1994, Revision X2, Draft.

> "4.2.2.3 Adjacent and Alternate Channel Selectivity
>
> "The minimum adjacent channel selectivity shall be 16 dB and the minimum alternate channel selectivity shall be 60 dB."

This is plotted on Figure ITFS-2 "Measured Spectrum Analyzer Selectivity".

If the spectrum analyzer is tuned to the center frequency of the highest MSS channel, the ITFS carrier will only be attenuated to -22 dBc, and the carrier response will overwhelm the -38 dBc specified for the emissions at the edge of the band. If the spectrum analyzer is tuned to the edge of the band, with the carrier offset from band center by 1.25 MHz, the spectrum analyzer will attenuate the ITFS carrier to only about -12 dBc.

However, using a Globalstar CDMA receiver filter in the highest MSS channel, the ITFS carrier level would be reduced to approximately -38 dBc (coincidentally equivalent to the -38 dBc specified for the edge of the band). But since the carrier will always remain at approximately the same level, whereas the sideband level will probably be lower, the primary interfering level into the CDMA receiver will still be the ITFS carrier response. However, through the CDMA filter, it will be 16 dB lower than as observed on the spectrum analyzer.

Therefore, ITFS interference in the highest MSS channel measured using the spectrum analyzer will indicate levels 16 dB higher than will be experienced by the CDMA demodulator. Or in other words, the ITFS interference that will be experienced by the CDMA demodulator will be 16 dB less than that observed on the spectrum analyzer.

ITFS Channel A1 Carrier Level, Measured versus Calculated

The two Figures ITFS-3a and 3b "ITFS Channel A1 Measured versus Calculated" show the results of a received signal strength measurement of an ITFS signal on channel A1. The San Francisco Bay was circumnavigated counter-clockwise to measure the potential interference of the transmitting site located on Grizzly Peak above Berkeley, California. Locations with odometer readings along the route were logged manually, along time for synchronizing with the computer-recorded time stamps.

The outbound route started in Palo Alto and proceeded across the lower end of the San Francisco Bay, up the east bay on Interstate 880 to 80, under the coverage area of the ITFS transmitting site, exiting from Interstate 80 north of Albany Hill, proceeding up tree-lined residential streets to Grizzly Peak Road, proceeding on Grizzly Peak Road adjacent to the base of the ITFS tower, and then down Claremont Avenue to College Avenue in Berkeley. 370 measurement sequences were recorded.

The return route continued from College Avenue in Berkeley, proceeded down the remainder of Claremont Avenue (to move radially away from the ITFS transmitting site), across the San Francisco Bay Bridge, through San Francisco, down the west bay on Bayshore Freeway, and ending at the SS/L facility in Palo Alto. 214 measurement sequences were recorded, less than the outbound route because a more direct route was taken on the return.

After the measurements were completed, the recorded data was post processed to reduce the amount of data to be plotted. The spectrum analyzer outputs 601 points of data per sweep, but the Excel spread sheet program used to evaluate the data can only accept 256 columns of data. Therefore data reductions of 3:1 and 10:1 were utilized. The post processing of each subset of 3 or 10 data points can be selected to be the maximum, average, minimum, or a single sample.

The charts of the measured ITFS received signal level show three traces, the results of maximum (weak line), average (bold line), and minimum (weak line) post processing of the data. The fluctuations between maximum and minimum indicates the influence of multipath, shadowing, and blocking along the route.

To obtain the calculated signal level, for each selected location the distance from the ITFS transmitter was obtained from a map and a calculation of the predicted signal strength was made. This took into account the specified ITFS transmitted EIRP of 49.7 dBm [EIRP = ERP(dipole) – 2.15 dB] and the antenna pattern with an elevation tilt.

The vertical antenna pattern was approximated with a *sinc* function for ease of calculation. See Figure ITFS-4 "Vertical Pattern of ITFS Antenna #1 at Grizzly Peak". The horizontal pattern is approximately 180° centered about an azimuth of 230° pointed toward San Francisco to cover Berkeley and Oakland. The antenna tilt was estimated to be downward 2.5° to match the measured data because the station engineer did not have the tilt on record. Distance and elevation angle from the transmitting site where used for calculating path loss and antenna gain. See Figures ITFS-5a and 5b "Elevation Angle & Distance from ITFS Transmitter at Grizzly Peak".

To plot the received signal level as if it were displayed on the spectrum analyzer screen, the 33.5 dB gain of the test-setup low-noise preamplifier was subtracted from the calculated received signal level. The receive antenna on the roof of the van is a half-wave dipole with a gain of approximately 0 dB and is omni-directional in azimuth.

The calculated signal strengths for the selected logged locations are plotted as points in Figures ITFS-3a and 3b along with the measured results. The calculated signal strengths approximate the peaks of the averaged post processed plot. The peaks of the maximum post processed data exceed the locus of calculated points because of multipath enhancement, which are observed to be greatest when conditions offer unblocked reflections from the San Francisco bay. Blocking from prominent hills, tunnels, and heavy tree shadowing can be identified. Over most of the ITFS coverage area, the received isotropic power (RIP) (the signal level received by an isotropic antenna) of the ITFS visual carrier varies between -70 and -80 dBm. At short distances (less than 2 miles from the ITFS antenna site), the RIP can be as great as -60 dBm.

Measured Spectrum Analyzer Levels of Highest & Second Highest MSS Channels

The two Figures ITFS-6a and 6b "Measured Spectrum Analyzer Levels" show the results of interference level measurements of an ITFS transmitter operating on channel A1 into the test setup receiver, which is a HP8561E spectrum analyzer. These interference measurements of the highest MSS channel and the next highest MSS channel were made consecutively with the measurement of the ITFS received signal (carrier) level.

The spectrum analyzer, under control of the PC, recorded a consecutive sequence of 4 sweeps.

1.	Frequency Sweep	
	Frequency Range:	2.410 to 2.510 GHz (100 MHz span) Includes most of ISM band and first two ITFS channels visual carriers.
	Resolution Bandwidth:	1 MHz Approximates Globalstar CDMA 3 dB bandwidth (but not 60 dB selectivity bandwidth)
	Video Bandwidth:	10 kHz
	Sweep Time:	2 seconds
2.	Time Samples	
	Frequency Span:	0 (Fixed tuned receiver)
	Resolution Bandwidth:	1 MHz Same as for frequency sweep
	Video Bandwidth:	10 kHz Same as for frequency sweep
	Sweep Time:	100 milliseconds
2.a.	Frequency:	Highest MSS channel, no guard band 2.499375 GHz (2.5 GHz – 0.5 x 1.25 MHz)
2.b..	Frequency:	Second highest MSS channel 2.498125 GHz (2.5 GHz – 1.5 x 1.25 MHz)
2.c.	Frequency:	Lower edge of MSS band 2.4835 GHz

One time sequence of 100 milliseconds duration was centered on the highest MSS channel center frequency. This is a worst case situation with no guard band, i.e., the upper edge of the MSS channel is contiguous with the lower edge of the ITFS channel.

The second time sequence was centered on the next highest MSS channel center frequency. This was to help determine the rolloff of the ITFS interference.

The third time sequence was centered on the lower band edge of the MSS band. This was to maximize the effect of ISM interference, which will be discussed in a separate report.

Post processing selected the average level of each sweep. To reduce the amount of data to be plotted to 10%, the data was further post processed to select the average signal level found within a set of 10 consecutive sweeps. For a constant amplitude carrier, the peak post processing and average post processing produced nearly identical results, but it believed that the averages present a truer picture of the interference potential. (Note that unlike ISM signals which are pulsed in nature, ITFS interference is of continuous nature and observing average power is valid. Each measurement sweep is of 100 milliseconds duration. During each sweep the transmitted carrier is of relatively constant level. The received signal level post processed in sets of 10 data points for maximum versus average shows little difference between them. If all things where held constant in the path, there should be no difference between maximum, average and minimum. The few dB variation observed indicates some multipath fading and shadowing was being experienced.)

The averages of the highest MSS channel and of the second highest MSS channel were on Figures ITFS-6a and 6b. The lowest MSS channel did not show evidence of ITFS interference and hence was not plotted.

The levels plotted are those indicated on the spectrum analyzer display. Corrections to be applied to indicate the received signal level to be experienced by a Globalstar CDMA demodulator are discussed below.

Calculated CDMA Demodulator Input Levels

The two Figures ITFS-7a and 7b "Calculated CDMA Demodulator Input Levels" indicate the effect of the ITFS interference from channel A1 upon the CDMA demodulator after filtering by the CDMA filter.

Two corrections to the measured data reported above must be made to determine the potential ITFS interference to the Globalstar CDMA receiver.

1. The low-noise preamplifier used for this measurement has a gain of approximately 33.5 dB. The signal level at the input to the preamplifier is then 33.5 dB less than that indicated on the spectrum analyzer display and on the charts, e.g., -70 dBm displayed is -103.5 dBm received.

   (Not having to continually add or subtract this gain value while working with the equipment in the field made it easier to verify measurements and compare results.)

2. The spectrum analyzer selectivity at -60 dB level is significantly broader than the planned Globalstar CDMA receiver selectivity. (See Figure ITFS-2 "Measured Spectrum Analyzer Selectivity".) The interfering signal levels, as measured by the spectrum analyzer with 1 MHz resolution bandwidth and centered in the highest MSS channel, is the ITFS channel A1 visual carrier at 2.501250 GHz attenuated by the

spectrum analyzer filter. The frequency offset from the center of the highest MSS channel to the ITFS visual carrier is 1.875 MHz, which produces an attenuation of approximately 22 dB to the ITFS visual carrier level.

The corresponding attenuation produced by the planned CDMA filter is approximately 38 dB. Therefore the interference level experienced by the CDMA demodulator will be 38 – 22 = 16 dB lower than measured with the spectrum analyzer, e.g., -70 dBm displayed is:

$$-70 - 33.5 - 16 = -119.5 \text{ dBm}.$$

The maximum permissible received ITFS interference level into a Globalstar CDMA receiver has been determined from exercising the link budget to be -101 dBm. This is under the condition that the aggregation of all other Globalstar MES on the channel are operating at average signal level and power control conditions. Only the single MES under examination requires operation in the ITFS coverage region and has called for maximum power control.

Two traces of Figures ITFS-7a and 7b show the modified levels of the highest MSS channel and the second highest MSS channel as compared to the maximum permissible interference level.

Conclusion

The only instance where interference would occur in the highest MSS channel is directly under the ITFS transmitting tower, all other locations will not experience interference which cannot be compensated by normal Globalstar operation. There are no incidences where the interference exceeds the interference limit for the second highest MSS channel.

Even if the Globalstar MES called for no power control, ITFS interference would result only directly adjacent to the ITFS transmitting site. ITFS transmitting sites are probably remote from the areas covered to gain the height advantage of hills or tall buildings or towers, and hence it takes a concerted effort to place a MSS MES in a potentially interfering location.

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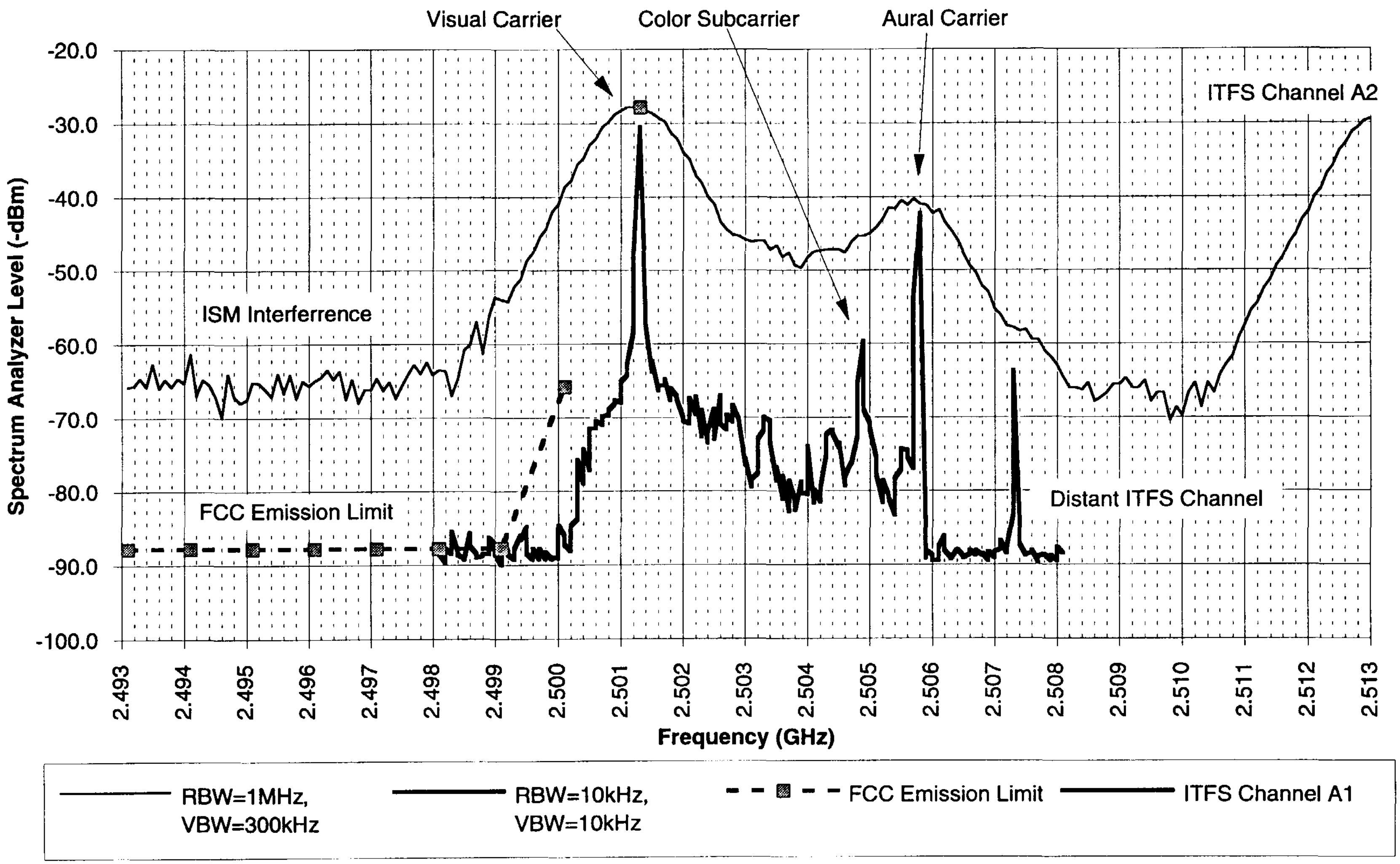
Figure ITFS-1

Spectrum of ITFS Channel A1 Located at Grizzly Peak, Berkeley, CA



Globalstar

Figure ITFS-2
Measured Spectrum Analyzer Selectivity
Specifications for ITFS Emissions and CDMA Receiver Selectivity

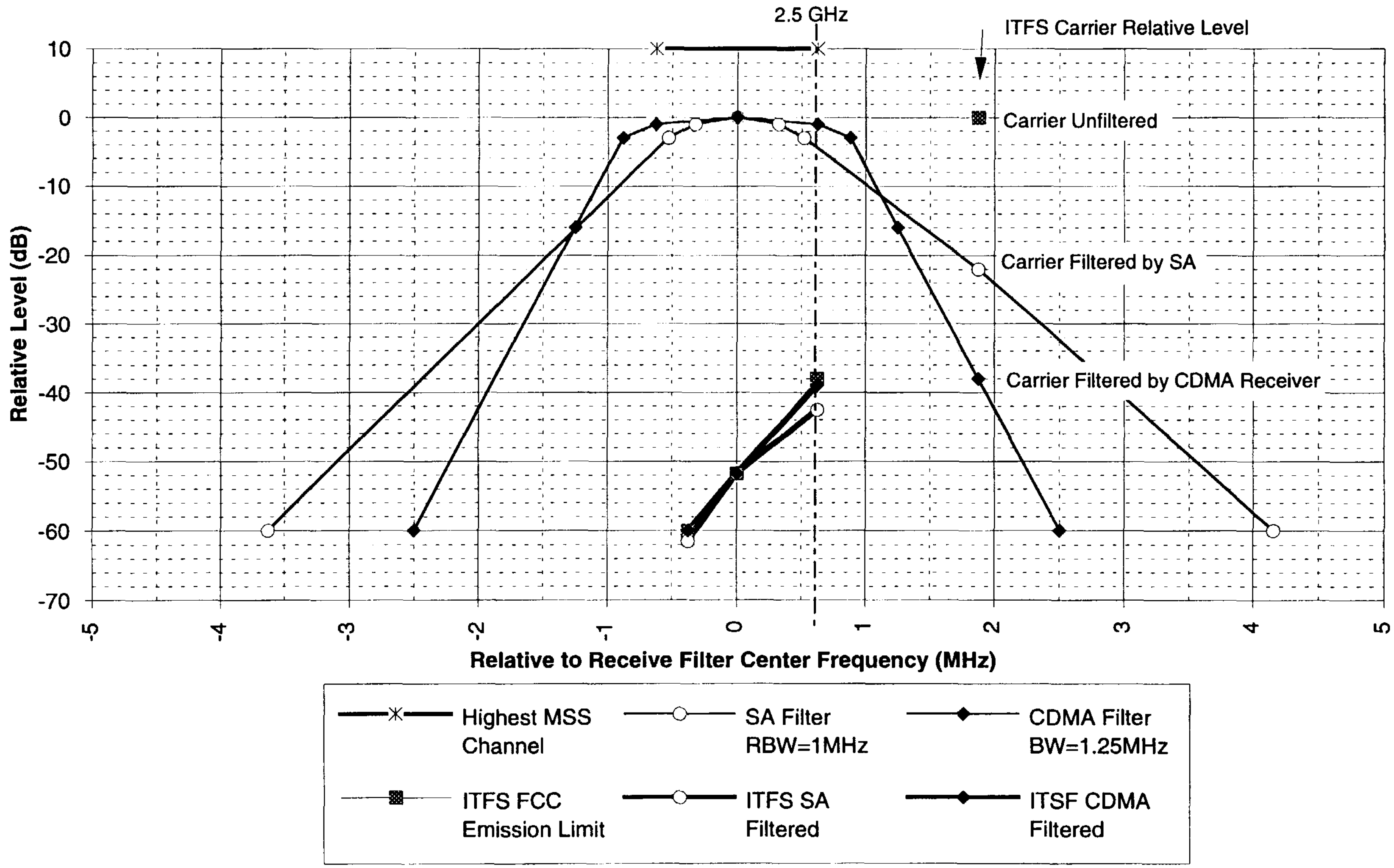


Figure ITFS-3a

ITFS Channel A1 Measured versus Calculated

Outbound, Palo Alto to Grizzly Peak, Berkeley

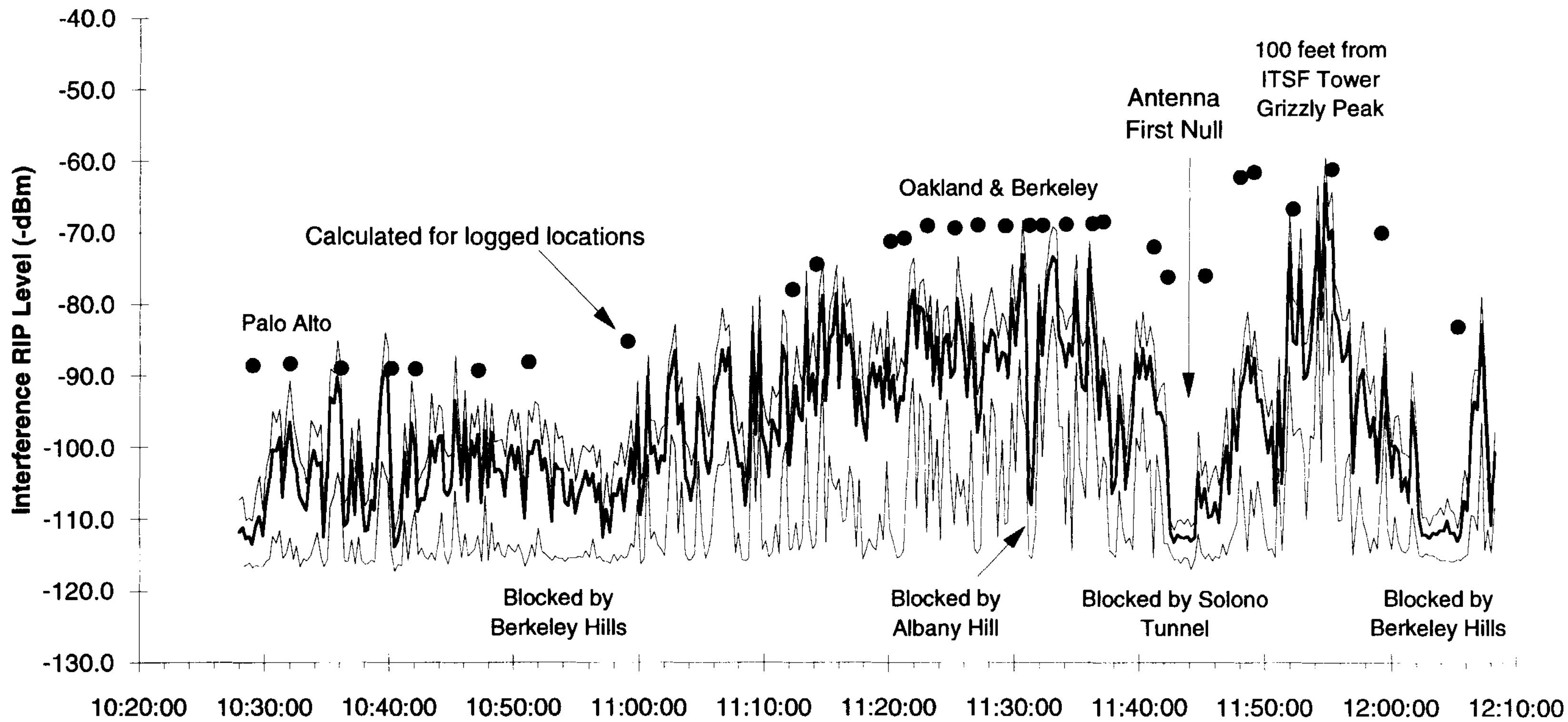


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Figure ITFS-3b

ITFS Channel A1 Measured versus Calculated